J Nanopart Res (2011) 13:1533–1548
DOI 10.1007/s11051-011-0227-0

SPECIAL FOCUS: GOVERNANCE OF NANOBIOTECHNOLOGY

Creating informed public opinion: citizen deliberation about nanotechnologies for human enhancements

Michael D. Cobb

Received: 7 January 2011 / Accepted: 13 January 2011 / Published online: 5 February 2011

Abstract Many people believe that ordinary citizens should influence scientific and technological developments, but the American public is routinely uninformed about these issues. As a solution, some scholars advocate creating informed public opinions by encouraging citizens to deliberate about the issues. Although this idea is currently widely applauded in the science and technology literature, deliberative outcomes are infrequently measured and the practice of deliberation is routinely criticized in other disciplines. This research contributes to our understanding of the effectiveness of citizen deliberation as a method for increasing public engagement with science. I report data measuring results of deliberation in a national citizens' technology forum (NCTF) about nanotechnologies for human enhancement. The NCTF was a month-long process involving six groups of 9–15 ordinary citizens who deliberated in different locations across the United States with the goal of reaching consensus about policy recommendations within their groups. I find that structured deliberation generated informed opinions, sometimes meaningful shifts in preferences, and increased trust and internal efficacy among the participants. Nevertheless, the NCTF has important shortcomings, and it is not obvious that consensus conferences should be preferred over other mechanisms for creating informed opinions. Future research is needed to corroborate the findings of this study and to systematically compare outcomes of structured citizen deliberation to other less resource intensive forms of engagement.

Keywords Nanotechnology · Public opinion · Deliberation · Human enhancement · Governance

M. D. Cobb (✉)
Department of Political Science, School of Public and International Affairs, North Carolina State University, Raleigh, NC 27695, USA
e-mail: mike_cobb@ncsu.edu

Introduction

For some time now, people in government, industry, and academia have been working to develop the potential of the so-called "converging technologies" of nanotechnology, biotechnology, information technologies, and cognitive science (NBIC) to enhance human abilities (Roco and Bainbridge 2003). The kinds of applications that might be created, such as implants to allow direct computer-to-brain linkages or medical devices that roam the blood stream searching for cancer cells, would certainly affect our social, cultural, economic, and political systems (Savulescu and Bostrom 2009; Hays 2010). Recognizing that public rejection of these technologies is possible, as occurred with genetically modified foods (Gaskell et al. 1999), the various stakeholders appear to accept the idea that, at least to some extent, the public should be involved in the planning and

development of such technologies (Macnaghten et al. 2005; Hamlett et al. 2008).

Unfortunately, an all too familiar finding in the literature is that the American public is poorly informed about the topics of science and technology (National Science Board 2010). The lack of public literacy about specific issues like nanotechnology has also been apparent since representative polling on the subject began (Cobb and Macoubrie 2004; Scheufele and Lewenstein 2005). Recent studies confirm that awareness remains low and that only minimal increases in knowledge have taken place over time (Scheufele et al. 2009). Likewise, the public is poorly informed about related applications, such as synthetic biology (Kahan et al. 2008) and human enhancements (Hays et al. 2011). Given the uniformly low levels of public awareness about emerging technologies, how can ordinary citizens hope to, or even be asked to, shape policies about complex things that are expected to significantly affect their lives?[1]

Until recently, the prevailing view within the scientific community and those involved in science communication held that the solution to the public's lack of knowledge about this topic was to offer them more science education. If only the public learned the same facts that scientists knew, so went the thinking, then people would be more receptive to scientific solutions to society's problems and be more likely to embrace new technologies. Yet, there is little evidence that this prescription of "more science education" has been helpful (Irwin and Wynne 1996; Nisbet and Scheufele 2009). Moreover, this approach arguably relegates citizen participation to the role of giving approbations after-the-fact.

Criticisms of this so-called "deficit model" of public understanding of science have resulted in significant resources being funneled into engaging the public with science (Grimes 2006; Einsiedel 2008; Delgado et al. 2010). The critical operational difference between citizen engagement models and science education is that the former is a two-way interaction between scientists and citizens (Rowe et al. 2004). The normative assumptions behind the validity of two-way communication about science are a profound departure from past experiences. As Powell and Colin (2009, p. 3) write, "Our engagement work is motivated by two central premises: (a) lay citizens should have a say in scientific and technological developments that will affect their lives and the broader society in significant ways and (b) lay citizens bring valuable knowledge and perspectives into decisions about scientific developments and decisions that include more diverse perspectives will be more robust." Thus, for many involved with running public engagement exercises, their overarching goal is the democratization of the scientific process by having citizens jointly determine the development trajectories of new technologies before they reach the commercialized stage (Wilsdon et al. 2005).

Public engagement with science: deliberative methods

Although a wide variety of public engagement techniques have been used for creating a dialog with the public (Bell 2008; Powell and Colin 2009), a growing number of scholars identify small group deliberations as an ideal method for generating informed public opinions (Sclove 1995; Guston 1999; Einsiedel and Eastlick 2000; Hamlett and Cobb 2006; Hamlett et al. 2008; Burri 2009; Nelson et al. 2009). Small groups have become the unit of analysis because scholars of science communication are pessimistic about successfully engaging the public as a whole (Nisbet and Scheufele 2009), and deliberative communication is favored because it presumably has advantages over other forms of communicating. Deliberation is understood to be a particularly sophisticated version of talking, listening, and reasoning. According to Habermas (1996), deliberation is argumentation based on a free and equal exchange. More than that, deliberative talk requires individuals to weigh carefully both the consequences of various options for action and how other will view these acts (Burkhalter et al. 2002). As Ryfe (2002) explains, deliberation occurs when claims are advanced, evidence is presented, and counterfactuals are considered.

In more pragmatic terms, it is said that dialog should be deliberative because the act of deliberation results in better decisions and better citizens (Pateman 1970; Barber 1984; Habermas 1996; Dryzek 2000; Luskin et al. 2002; Dryzek and List 2003; Gutmann and Thompson 2004; Ackerman and Fishkin 1994;

[1] In addition to knowledge as a barrier to effective citizen input, there are other systematic barriers to citizens' participation on these kinds of issues, but a discussion of these factors is beyond the scope of this research (see Fischer 2000).

Gastil and Levine 2005). When theorists contend that deliberation produces better decisions, they mean that collective and individual decisions are superior to those reached after non-deliberative discussions or those commonly plumbed through representative polling. Rawls (1971), for example, writes that deliberation uniquely allows "each person [to] share what he or she knows with the others, making the whole at least equal to the sum of the parts."[2] At the micro-level, deliberation results in individuals' preferences becoming more congruent with their objectively defined interests (Fishkin 1991, 1997; Ackerman and Fishkin 1994; Luskin et al. 2002; Barabas 2004). Better citizens also emerge after deliberating because this distinct type of communicative activity encourages civic participation by increasing citizen's social capital (Putnum 2000). Theorists are normatively interested in increasing social capital because its components—knowledge, efficacy, trust, and civility—are thought to be core perquisites of a healthy democracy (Delli Carpini et al. 2004; Morrell 2005).

While the idea of citizen deliberation has thus far received almost uniformly positively reviews by scholars in the science and technology community, not everyone agrees that promoting deliberation as a method for public engagement is a good idea.[3] Surprisingly, very few empirical studies in the science and technology literature have measured the effects of deliberation, and the evaluative data that does exist is vulnerable to questions about comparability.[4] More to the point, deliberation has a host of critics in other disciplines (Stokes 1998; Hibbing and Theiss-Morse 2002; Sanders 1997; Sunstein 2000, 2003, 2005; for a thorough review, see Mendelberg 2002). One of their arguments is that deliberation is unnecessary because citizens already arrive at reasoned judgments though an efficient use of cognitive shortcuts (Lupia 1994; see also Schuefele (2006) for an explanation of the kinds of heuristics citizens rely on when considering science and technology issues). Skeptics also question the wisdom of having citizens deliberate because they believe it creates normatively undesirable outcomes. Hibbing and Theiss-Morse (2002), for example, argue that people do not like to deliberate and that civility becomes a victim to excited passions when citizens are forced to deliberate. Moreover, deliberation is faulted for two, ironically, contradictory pathologies of decision-making found in public opinion research: the tendency of individuals to resist new, yet pertinent information and remain wedded to their original beliefs (Kuklinski et al. 2001) and to readily adopt the positions of the majority due to social pressures and regardless of the veracity of the majority's position (Sunstein 2003, 2005). In the first case, deliberation becomes a waste of time. In the second, distorted individual and group judgments arise to diminish the value of engaging the public with communication about science technologies.

Methodology

This study contributes to our understanding of citizen deliberation about science by empirically evaluating multiple outcomes of a national consensus conference about emerging technologies to enhance human abilities.[5] Held simultaneously across six cities, this event was called "the National Citizens' Technology Forum" (NCTF). Since consensus conferences have been described in great detail elsewhere (Grundhal

[2] It is difficult to measure whether group decisions are "better" as a result of deliberation because this judgment requires an independent, objective standard to evaluate the deliberative decision against and we normally lack appropriate measures. Instead, group-level outcomes are labeled "better" because procedurally they incorporate the normative standard that including more voices in the decision making process confers greater legitimacy on binding decisions (Gutmann and Thompson 2004).

[3] A critical question that has been raised about the practice, not the concept, is whether the "top-down" structure of deliberative events means they are problematic because organizers determine who gets to deliberate and what they deliberate about (Powell and Kleinman 2008).

[4] One unresolved issue when evaluating deliberative effects is that the science and technology literature often conflates deliberation, properly defined, with almost any kind of group talking about an issue. Some studies dubiously take for granted that their study design, which encourages citizens to discuss the issues, is equivalent to generating deliberation (see Sprain and Gastil 2006).

[5] Although I do not present direct evidence that citizens deliberated in line with theoretical descriptions, there are at least two reasons to believe it happened. The first reason is that consensus conferences are intentionally designed to foster deliberation and not mere discussion. Their very structure is developed from theory to support the occurrence of deliberation. Secondly, participants scored near the maximum on a scale measuring a personal willingness to deliberate, both prior to and after deliberating.

1995; Einsiedel et al. 2001; Hamlett 2002; Guston 1999; Brown 2006), and several in-depth explanations of the NCTF process have also been written (Hamlett et al. 2008; Delborne et al. 2009; Wickson et al. 2011), I avoid unnecessarily repeating their fuller descriptions here.

In short, consensus forums are resource intensive processes where approximately 10 to as many as 15 ordinary citizens come together in a small group to deliberate, usually face-to-face, over many weeks about a specific topic and generate policy recommendations based on consensus rules. In advance of these conferences, organizers often provide the participants with voluminous amounts of background information. During the conference, organizers ensure participants have access to additional information and experts. A typical conference also uses a trained facilitator to help participants determine appropriate tasks and deliberate toward a consensus report. In Denmark, the Danish Parliament's Board of Technology takes the panelists' final set of policy recommendations to parliament and distributes them to both the press and the public.

The NCTF is a modified version of the consensus conference process that was adapted to work in the more geographically challenging American context. The principal novelty of the NCTF is achieved by hosting multiple sites simultaneously and adding the Internet as a mode of deliberative interaction. According to the literature, the use of the Internet could provoke negative behaviors because face-to-face interaction has been found to increase cooperation among participants (Sunstein 2001). Yet, online communication permits the construction of deliberations involving multiple groups of citizens in multiple geographic locations. Analysis of using Internet technology in a prior, smaller-scale citizens' forum (Hamlett and Cobb 2006) indicates that it is not inherently problematic for successfully promoting deliberation, but an evaluation of its effects on deliberation within the NCTF is more critical (Delborne et al. 2009).

In March 2008, the NCTF was held in six distinct cities spread across the United States. Conference organizers at each site location used targeted advertisements to recruit applicants who filled out an applicant survey. To encourage applications and to compensate participants for their extensive time commitment to the projects, participants were awarded a $500 stipend distributed after completing the consensus conference. Over 350 citizens applied, 89 of them were ultimately selected to participate, and all but four of this group attended the first meeting.[6] A core objective in the process of choosing panelists from among the applicants was the maximization of the representativeness of group members compared to the demographics of their community and the United States at large. Of course, it is not possible, strictly speaking, to achieve representativeness of all community demographics within small groups, but the NCTF panelists overall reflected a reasonable approximation of the American public on several important demographic characteristics (Hamlett et al. 2008).[7] Importantly, panelists were also similar to most Americans in terms of being uninformed about the issue. Most panelists (58%), for example, reported hearing "nothing" or "just a little" about nanotechnology before learning and deliberating about it. Finally, efforts were made to weed out individuals with self-interested agendas, such as interest group partisans, who would be unwilling to engage in deliberation.

Participants received a 61 page background document before the first meeting that was balanced, vetted by experts, and included heterogeneous viewpoints. The material was also written in lay language for non-experts to absorb. Furthermore, during the conference, access to information was guaranteed through interactions with experts and by granting requests for specific materials. Procedurally, participants deliberated face-to-face in their respective geographic groups for one weekend at the beginning of the month, and they deliberated electronically

[6] Organizers at each site location made the recruitment decisions, but all were in agreement that balancing socio-economic characteristics was a priority. Given the skewed demographics among the volunteers, random selection of panelists was impossible. Additional details are provided in Hamlett et al. (2008).

[7] For example, half the originally selected panelists were women, 65% were white, and the median age and income were, respectively, 39 years old and $50,000–$75,000. However, panelists were unevenly distributed political partisanship and political ideology (e.g., while 44% identified as Democrats, just 9% said they were Republicans and 36% reported being independent). During the recruitment of applicants (of which only 11 were Republicans), attempts were made to encourage non-Democratic applicants to take part in the NCTF, but these efforts were unsuccessful.

across their geographic groups in nine, 2-h sessions during the rest of the month. Electronic deliberations included question-and-answer sessions with a diverse group of topical experts.[8] When citizens engaged in online deliberation, a professional facilitator made sure that all participants had opportunities to speak and ask questions, and intervened if necessary to ensure participants' dialog remained respectful.[9] The NCTF concluded with a second face-to-face deliberation at each site. At the final meeting, participants drafted reports that represented the consensus judgments of their local groups.[10]

Measures

In order to evaluate the effects of deliberation in the NCTF, participants were required to complete a lengthy pre-test and post-test questionnaire.[11] In addition to basic demographics, data were gathered measuring participants' knowledge and opinions about nanotechnology and human enhancement, and their self-reported feelings of efficacy and trust in others (precise question wording and answer options for all data are located in the Appendix). The pre-test was taken on-line before their first face-to-face meeting, and the post-test was taken on-line soon after the groups generated their consensus reports. Although 89 of the selected participants completed the pre-test, four of them did not attend the first meeting and 12 panelists did not complete the post-test. Thus, these individuals were dropped from any within-subjects analysis of deliberation. As a result, opinion change is typically measured using at most 73 individual's survey answers.[12] My analysis of respondents with missing post-test data indicates all but two of them were white, and they were disproportionately wealthier (family income of $75,000 or more) and highly educated (some graduate school or a graduate degree). As a result, the over-time comparisons are actually conducted on a smaller, but overall more diverse and representative sample than was originally obtained.

Knowledge

Informed opinions depend on holding accurate factual knowledge about the issue (Fishkin 1997). Learning about NBIC technologies and human enhancement was measured by asking panelists to answer six factual multiple-choice questions. Answers to each question were used to create a simple additive index by assigning correct answers a value of "1" and incorrect answers a value of "0" (i.e., respondent's values on the index can range from 0–6). However, after each knowledge item, panelists were also asked to report how confident they felt about their answer, or to admit that they had guessed. Using this additional information, I created a second and novel knowledge index to control for guessing, penalize confidently holding inaccurate beliefs, and reward knowing correct answers confidently. For example, respondents were not awarded a point when they correctly answered a question but also admitted to guessing (score = "0"). Likewise, a point was deducted ("−1") for answering a question incorrectly, yet confidently. Finally, respondents were awarded an additional point if they reported feeling very confident about their correct answers (a score of '2" rather than "1"). As a result, individuals' scores on this modified knowledge index could range from −6 (i.e., all confidently wrong answers) to +12 (i.e., all confidently correct answers).

[8] The content experts included technical specialists, a philosopher, and a specialist in regulatory processes.

[9] Each site had different facilitators to manage the face-to-face deliberations. While the primary NCTF organizers gave instructions and advice for how to maintain consistent and professional facilitation, variation in the actual management of deliberation could have occurred and contributed to occasional differences in outcomes across site locations.

[10] The role of consensus is disputed in debates about definitions of deliberation. The pressure to reach consensus outcomes in deliberative settings is thought by some to exacerbate conformity effects and produce group delusion that "overwhelms the perspectives" of individual members (Mackie 2002).

[11] Importantly, it should be recognized that this research design is quasi-experimental. Participants were not randomly selected or assigned to conditions, and there are unmeasured influences arguably affecting behaviors beyond the treatment of deliberation, such as anticipation of the conference and informal conversation outside of the conference meetings with non-participants.

[12] Most of the people that did not take the post-test dropped out before the final meeting, but sometimes a panelist simply failed to answer the identical question at both points in time.

Opinion change

Does deliberation about NBIC technologies change citizens' opinions about them?[13] One interpretation of opinion change after deliberation is that it represents the difference between uniformed and informed opinions. As Luskin et al. (2002, p.458) explain, an exercise in deliberation is "designed to show what the public *would* think about the issues, if it thought more earnestly and had more information about them." Deliberation does not guarantee that opinions will change or that they will change in a particular direction, but it means that the opinions held after deliberating are superior because they are based on better quality information. Nevertheless, the general expectation is for opinions to look different afterward, or else why would deliberation matter? Opinion change is examined over multiple measures, such as, "What do you think about the risks and benefits of using nanotechnology for human enhancement, such as creating superior performance and longer, healthier lives?"

Polarization cascades

If opinions do change, can we be sure this occurred for normatively desirable reasons? As critics of deliberation observe, polarization cascades are another reason opinions might shift within deliberating groups. Polarization cascades occur when individuals holding the minority opinion in a group adopt the majority's opinion due to the sheer numerical advantage of one side's arguments during a debate, not because those arguments are qualitatively superior (Sunstein 2003). Over time, this is a dynamic process that has the potential to polarize group preferences into ever-larger majorities holding one view and shrinking minorities opposed. A simple way to test for the presence and strength of polarization cascades is to measure the direction of mean opinion change compared to the original group position about an issue. Does the initial majority position within a group consistently attract more people to that side after they deliberate about it? Also, do the ranges of opinions decrease after deliberation, identified as a reduction in the standard deviation of mean opinion on each issue compared to its pre-deliberative standard deviation in opinion? Of course, patterns of group-level opinion change that are consistent with descriptions of polarization cascades is not unequivocal evidence that the substantive outcome of decision-making is problematic,[14] but consistent patterns like these would provide some support for the viewpoint that deliberation can lead to poor group decision-making processes.

Efficacy

Two concepts central to debates about the value of citizen deliberation are internal (IE) and external (EE) political efficacy (Morrell 2005; Mattei and Niemi 2005). Feelings of political competence are an important theoretical benefit of deliberation (Pateman 1970), and IE and EE are thought to be key dimensions to perceived competence. Following Morrell (2005), I used four validated questions with answers measured on a standard 5-point agreement/disagreement scale to create an additive scale measuring IE (i.e., "I consider myself well qualified to participate in politics"). Cronbach's alpha for the pretest and posttest IE scales were .66 and .77, respectively. Following Craig et al. (1990), a scale measuring EE was developed using two items (i.e., "People like me don't have any say what the government does"). Chronbach's alphas for the pretest and post-test were, respectively, .68 and .80.

Trust

Having trust in others is also an important indicator of social capital and a potential benefit of deliberation (Putnum 2000). Following Craig et al. (1990), I created a generalized trust scale by adding answers to three dichotomous survey items (i.e., "Do you think most people would try to take advantage of you if

[13] Although I do not report the actual consensus reports of the six groups in this research, they provide solid evidence that thoughtful learning took place (Hamlett et al. 2008), and are accessible to general public at http://www4.ncsu.edu/~pwhmds/final_reports.html.

[14] Imagine, for example, that before deliberation ten out of fifteen people thought Hitler's rise was a catastrophe, and that after deliberating all fifteen agreed it was a catastrophe. While the shift in opinion is consistent with the process of polarization cascades, it is unlikely that anyone would seriously object to the substantive shift in opinions.

they got the chance, or would they try to be fair?"). Trusting answers were scored a "2" while untrusting answers received a "1". The resulting trust scale ranges in values for individuals from 3–6, and they generated Cronbach's alphas of .61 and .73, respectively, in the pre-test and post-test.

Results

Knowledge

I start the analysis by presenting results for panelists' learning about nanotechnology and human enhancements. These data are located in Table 1. Looking first at the simple additive index of knowledge before deliberating (KNOWSCORE), I find that panelists answered, on average, about four of the six questions correctly. Afterward, panelists' average KNOWSCORE increased to more than five correct answers. The increased factual knowledge represents a modest, but statistically significant improvement among the panelists. It is important to recognize, however, that even though increased factual knowledge might be an intuitive result of deliberation, it was not guaranteed to occur and the effects of deliberation on knowledge are rarely demonstrated.

The traditional way of constructing a knowledge index, however, arguably overestimates how much people leaned by failing to control for guessing, and it certainly does not take confidence into account. Thus, I created a second knowledge index (KNOW + CONF), which punishes correctly guessed answers and rewards confidently answered ones. In contrast to the traditional knowledge index, my second measure of knowledge reveals that learning was more deeply affected by deliberating. Before deliberations took place, the average score on KNOW + CONF was less than four out of twelve possible points. After deliberation, the average score more than doubled to about nine points. This finding is particularly noteworthy given panelists' scores approached the maximum obtainable score of twelve points. It also demonstrates the importance of conceptualizing knowledge as more than measuring correctly versus incorrectly answered questions.

Table 1 Effects of deliberation on panelists' knowledge about NBIC technologies

	Pre-deliberation	Post-deliberation
KNOWSCORE	3.97 (1.6)	5.27 (1.0)**
KNOW + CONF	3.72 (3.8)	8.96 (2.9)**

Note: Entries are means; standard deviations in parentheses; ** $P < .01$, paired sample, one-tailed *t*-tests; $N = 71$ for both scales

While knowledge gains represent a valued outcome independent of their effects, we would also expect to find that the more confident and accurate a person is about the facts, the more likely they would be draw upon their knowledge when formulating opinions. Deliberative theorists would presumably endorse this type of process. Unfortunately, in analysis unreported here (available upon request), I consistently find that, regardless of how the knowledge measures were constructed, these scores fail to explain opinions or opinion change after deliberation. One possibility for these null effects is that the factual content measured in this study had no logical bearing on opinion formation regarding the opinion questions that were asked. It is also possible that issue opinions are formed for reasons other than factual information about the issue. I explore this possibility later in the analysis.

Opinion change

In this section, I present descriptive data about opinion change. Do people become more critical or accepting of these technologies after learning more about them?[15] If these data represent the difference between uninformed and informed public opinion about the topic, they can also point to how public opinion in general might develop in more ideal settings. Since panelists were asked many more questions than can be reported here, I focus on reporting a sub-set of survey items to illustrate what transpired in general during the NCTF (the full set of survey questions and answers is available upon request). As before, these data are presented in

[15] Many more people changed their opinions over time than these results indicate, but I am more concerned with the potential for "net attitude change" than with measuring response variation for its own sake (see Luskin et al. 2007). The reason for this emphasis is because democratic outcomes are not affected by equal percentages of the population changing their minds in opposite directions, no matter how large the magnitude of gross opinion change.

aggregate form, not by site location, because the potential influence of group dynamics on opinion change is a separate matter that is analyzed afterward.

I start by presenting panelists' opinions about five hypothetical NBIC applications in Table 2, before and after deliberation. Panelists' initial level of support varies depending on the application, with many people failing to have an opinion. A solid majority of participants support just one application, but a plurality supports two others and one application is opposed by a simple plurality. After deliberation, however, opposition became the norm. Almost everyone continued to support the one application described as preventing healthy from becoming sick, but opposition increased to all other possible applications, and these differences in opinions were statistically significant in three of the four cases. As a result of these shifting opinions, an outright majority now opposed two of the applications and a plurality opposed the remaining two. Overall, these findings are consistent with representative polling that shows Americans' only support human enhancement applications that are narrowly tied to health benefits, or therapies, such as the prevention of cancer (Hays et al. 2011).[16]

Next, I examine opinions about trust in the federal government and business to protect the public from risks associated with nanotechnology. These data, presented in Table 3, indicate a glaring absence of trust in either institution. Business fares particular poorly. In the pre-deliberation survey, just 13% expressed a great deal or a fair amount of trust in business, and this percentage did not increase post-deliberation. Trust in the federal government was slightly higher to start than for business, and it edged upwards over time, although the increase was not statistically significant. The higher degree of trust in government compared to business after deliberation, however, is statistically significant.

In Table 4, I present results for panelists' perceptions about the risks versus benefits of using nanotechnology for human enhancements. There are two interesting patterns to the opinion change seen here. First, a sizeable amount of opinion change on this question is mostly the result of panelists forming opinions after deliberating. A majority could not even offer an opinion at first, but almost everyone had an opinion at the end of the NCTF. While this finding might seem mundane, it supports the argument that deliberation allows people to better understand their own interests though exposure to facts and argumentation (Luskin et al. 2007). A second finding is that opinion formation was not unidirectional. Roughly equal percentages of panelists who lacked an opinion at first came to see using nanotechnology for human enhancements as more risky or as more beneficial, not equally risky and beneficial. This suggests exposure to communication about a technology's risks does not inevitably result in greater public opposition to that technology, as some have feared. Indeed, after deliberations almost a majority now believed the benefits would exceed the risks.

Opinions about the costs of enhancements, and who should pay for them, are presented in Tables 5, 6, and 7. Overall, opinions indicate a certain degree of ambivalence that persisted after deliberations concluded. A majority of panelists originally believed enhancements would be too costly for most Americans, and deliberations did nothing to deter them from thinking this would be true. Indeed, a slightly higher, but not significantly different, percentage of panelists thought after deliberating that only the wealthiest Americans could afford them. When pressed about how to determine access, most thought government should guarantee access to enhancements rather than personal wealth, a feeling that increased somewhat after deliberating, although again the direction of opinion change was not statistically significant. Interestingly, one-quarter of panelists were still unsure about what to think when they were asked this question after deliberating about it. Not only does the remaining degree of uncertainty suggest the topic is complex, it also demonstrates that opinion formation is not inevitable, so it should be taken seriously when it occurs. Panelists' answers to a third question complete the picture of ambivalence and complexity. When pressed to choose between medical insurers covering enhancements or individuals being responsible for paying for them, a plurality at first said insurance should pay. After deliberating, roughly equal proportions were unsure who should pay. Some remained literally unsure, while nearly

[16] As was almost always the case for within site analysis of opinions, the directional change of opinion on all five applications was identical, except once when panelists at Santa Barbara became more supportive of nanotechnologies to prevent prisoner escapes.

Table 2 Panelists' support for five hypothetical NBIC applications, before and after deliberating about them

Application	Pre-deliberation		Post-deliberation	
	Oppose (%)	Support (%)	Oppose (%)	Support (%)
Implants using nano-wires to transmit information directly from the brain of one person to another person	30	31	51	11**
Brain enhancements that transmit information from computers or other sources of information to a person while they sleep	27	37	40	26**
Nanotechnology based drugs administered to prisoners to prevent prison escapes	41	34	51	26
Implanting bionic eyes into humans to achieve extreme magnifying and zooming in abilities	14	32	36	29**
Implants to be used for detecting changes in biomarkers and protein levels in humans to catch diseases before they become dangerous	1	89	3	89

Note: Entries are percentages; ** $P < .01$, paired sample, two-tailed *t*-tests; Minimum $N = 73$

Table 3 Effects of deliberation on panelists' confidence in the federal government & business to protect the public from significant risks associated with nanotechnology

	Federal government**		Business	
	Pre	Post	Pre	Post
A great deal + a fair amount of confidence	21%	28%	13%	13%
Some confidence	31	38	28	28
Very little confidence	26	32	44	59
Not sure	22	2	15	0
N	85	68	85	68

Note: Entries are percentages; ** $P < .01$, two-tailed t-test of the different levels of confidence across institutions, post-deliberation

Table 4 Effects of deliberation on panelists' perceptions about the risks versus benefits of using nanotechnology for human enhancement

Opinion	Pre-deliberation $N = 85$	Post-deliberation $N = 68$	Difference
Risks > Benefits	6%	28%	+22%
Risks = Benefits	16	23	+7
Risks < Benefits	23	46	+23
No opinion	55	3	−52

Note: Entries are percentages' opinion change between pre- and post-deliberation was *ns*

identical percentages thought medical insurance should pay or that individuals should pay. On this question, opinion change was significantly in one direction—18% more thought individuals should pay for enhancements, while 2% fewer said the same about insurance.

Polarization cascades

It is difficult to determine the precise reasons opinions changed in a particular direction without content analyzing the quality of deliberations. Were preferences different at the end of the NCTF because panelists engaged one another in thoughtful argumentation, or did they change their minds because of undesirable decision-making processes? One way to answer this question is to look for properties of opinion change consistent with polarization cascades. If opinions are affected by polarization effects, then the average group position on any issue will routinely move further in the direction of opinions espoused by the initial majority within a group, and the variance in the distribution of their opinions on these measures should decrease. As before, space does not permit an examination of every issue opinion, so I examine three items where opinions changed significantly. The results reported here for these three items are

Table 5 Panelists' thoughts about the affordability of human enhancements when they are brought to market, before and after deliberating

	Pre-deliberation	Post-deliberation
Affordable for most Americans	9%	11%
Too costly for the average American	55	56
Available to only the wealthiest	18	25
Unsure	18	8
N	85	72

Note: Entries are percentages; opinion change between pre- and post-deliberation was *ns*

Table 6 Panelists' opinions about access to obtain human enhancements, before and after deliberation

	Pre-deliberation	Post-deliberation
Wealth should determine access	8%	10%
Government should guarantee access	57	64
Unsure	35	26
N	*85*	*72*

Note: Entries are percentages; opinion change between pre- and post-deliberation was *ns*

Table 7 Panelists' opinions about insurance covering most kinds of human enhancements, before and after deliberation

	Pre-deliberation	Post-deliberation*
Medical insurers should pay for them	40%	38%
Individuals should have to pay out of pocket	14	32
Unsure	46	30
N	85	72

Note: Entries are percentages; * $P < .05$, two-tailed test for mean opinion change between pre- and post-deliberation

consistent with my analysis of other survey measures (the full set of results is available upon request).

The data in Tables 8, 9, and 10 are ordered by the site location, since each deliberating group is now the proper unit of analysis. Results include the mean opinion and its standard deviation, before and after deliberation. I also indicate whether any difference in these variables occurs in the direction predicted by polarization cascades (yes or no) and if opinion change within a site location is statistically significant. Since all survey questions that I analyze were measured on three-point scales, polarization is determined by comparing the movement of group opinions to the midpoint of these scales, or "2." Initial means above two are predicted by critics to increase after deliberation, while means below two should decrease after deliberation.

I start by reexamining panelists' perceptions about the risks versus benefits. Was the opinion change presented in Table 8 a consequence of undesirable group dynamics? The short answer is no. Opinions at only one of the six sites (AZ) shifted in the predicted direction, and this difference was not statistically significant. Conversely, group means moved in the opposite direction, or not at all, at the other five locations, and once this difference was statistically significant. The results for the variance in opinions are nearly identical. Just one site (WI) experienced a reduction in the variation in expressed opinions.

Results for how worried and hopeful panelists are about these new technologies, presented in Tables 9 and 10, also reveal limited evidence of feared polarization effects. Looking first at worrying, average feeling across all sites were originally below the mid-point of the scale, indicating an overall lack of worrying to start. Yet, worrying increased or stayed the same rather than decreasing further. In addition, theoretically the CA group was the one that should have experienced the most polarizing effects of deliberation since they started out the least worried on average, but this was the site of largest counter-attitudinal change.[17] As before, the variance in feelings actually increased after deliberation at all but one site (WI).

The results for feeling hopeful are only a little less clear. All six groups reported feeling hopeful about human enhancement technologies scale before deliberations (i.e., scores above the mid-point), and this feeling either remained constant or increased across

[17] One problem is that this comparison is based on just three individuals who expressed feelings at both points in time. Yet, when I examined the distribution of opinions among panelists with no feelings at first compared to their reports after deliberating, the same pattern occurs. The panelists who only took a position at the end expressed more worry than their fellow group members who had answered the question at the beginning. This pattern is replicated within sites with low response rates for feeling hopeful.

Table 8 Group means test for polarization cascades on the question of risks versus benefits of nanotechnology used for human enhancement

CTF location	Pre-deliberation means	Post-deliberation means	Mean opinion change support polarization hypothesis?	Pre-deliberation variance	Post-deliberation variance	Variance supports polarization hypothesis?
AZ	2.1	2.3	Yes	0.5	0.9	No
CA	2.4	2.3	No	0.5	0.8	No
CO	1.8	2.2*	No	0.4	0.9	No
GA	2.3	2.3	No	0.5	0.9	No
NH	2.0	2.2	NA	0.4	0.7	No
WI	2.5	2.1	No	0.7	0.6	Yes

Notes: The midpoint of the scale = 2 (risks = benefits); means below the midpoint indicate risks > benefits and means above the midpoint indicate benefits > risks; Site *N*'s vary from 7–14; * $P < .05$, for differences between pre- and post-deliberation opinions, one-tailed paired sample *t*-tests

Table 9 Group means test for polarization cascades on the question of worrying about nanotechnology used for human enhancement

CTF location	Pre-deliberation means	Post-deliberation means	Mean opinion change support polarization hypothesis?	Pre-deliberation variance	Post-deliberation variance	Variance supports polarization hypothesis?
AZ	1.7	1.7	No	0.8	0.5	Yes
CA	1.3	2.3	No	0.6	0.6	No
CO	1.6	2.0	No	0.5	0.7	No
GA	1.7	1.9	No	0.5	0.5	No
NH	1.8	2.2	No	0.4	0.4	No
WI	1.9	1.8	Yes	0.6	0.4	Yes

Notes: The scale midpoint is the neutral position on the opinion measure; means below the midpoint indicate being unworried and means above the midpoint indicate being worried. Site *N*'s vary from 6–14; * $P < .05$, for differences between pre- and post-deliberation opinions, one-tailed paired sample *t*-tests

all locations. Yet, the magnitudes of these increases were always substantively marginal and none were statistically significant. Furthermore, just two sites experienced a reduction in the range of feelings on this question, contrary to critical expectations. Thus, while the direction of effects on this measure is more consistent with claims about polarization cascades than data for the prior two questions, the effects are weak and inconsistent, and they probably would not generate much alarm, especially since feeling worried, which is orthogonal to feeling hopeful, also increased after deliberations.

Social capital

In the final set of analyses, I report the effects of deliberating on three core components of social capital: internal and external efficacy and general trust. These data are presented in aggregate level form in Table 11 since I am testing whether deliberation leads to "better citizens" overall.[18] Overall, the results lend some support to proponents' claims about the benefits citizens receive from deliberating, but the evidence is inconsistent and weak. The general concept of trust, for example, increased after deliberation ($P < .10$), but the magnitude of the increase was modest. A bit more impressively, participants' internal efficacy increased after deliberation, and the change in IE was both substantively meaningful (.8) and statistically significant ($P < .05$). In other words, by the end of the NCTF, participants saw themselves as being more capable of

[18] As before, I did not find any significant differences within sites compared to the overall movement of opinions.

Table 10 Group means test for polarization cascades on the question of feeling hopefulness about nanotechnology used for human enhancement

CTF location	Pre-deliberation means	Post-deliberation means	Mean opinion change support polarization hypothesis?	Pre-deliberation variance	Post-deliberation variance	Variance supports polarization hypothesis?
AZ	2.5	2.5	No	0.5	0.5	No
CA	2.8	2.8	No	0.4	0.4	No
CO	2.3	2.5	Yes	0.5	0.5	No
GA	2.3	2.4	Yes	0.7	0.5	Yes
NH	2.2	2.4	Yes	0.4	0.5	Yes
WI	2.5	2.8	Yes	0.5	0.5	No

Notes: The scale midpoint is the neutral position on the opinion measure; means below the midpoint indicate being unworried and means above the midpoint indicate being worried. Site *N*'s vary from 7–14; * $P < .05$, for differences between pre- and post-deliberation opinions, one-tailed paired sample *t*-tests

understanding and grappling with policy decisions. On the other hand, and contrary to expectations, participants reported feeling less externally efficacious after deliberating. While the decline in EE was also modest (about three-tenths of a point) it was statistically significant ($P < .05$), suggesting panelists were less likely to believe their actions would actually affect policy outcomes, even though they felt more competent about doing these things.

Conclusions and implications

Many science and technology scholars advocate for promoting greater public engagement with science because they believe ordinary citizens should be included in the policy-making process. Increasingly, public engagement efforts have been designed to promote deliberation because theorists contend that the specific and unique act of deliberation leads to better decisions and better citizens. The empirical evidence for these claims, however, has been scarce. What happens when citizens deliberate about science and technology issues?

This study finds evidence to support several of deliberation's theorized benefits. First, the depth of citizens' learning about these technologies was impressive. Second, net opinion change was frequently observed. Participants became more worried about the risks, but they also became more hopeful about the possibilities. Initial skepticism about enhancements versus therapies solidified, but increasing perception of risks were matched by increasing perceptions of benefits. Altogether, these results seem to be a clear indication that deliberation in the NCTF created informed opinions, exactly as it is intended to do. Yet, I also found that opinion change was infrequently correlated with levels of factual knowledge. It is unclear why learning about nanotechnologies for human enhancement was only sometimes linked to opinion change about the issue. One explanation is that opinion change was based on reasons other than factual knowledge, but I can at least rule out the normatively undesirable process of social pressure (i.e., polarization cascades). Thus, the most likely explanation is that the kinds of knowledge measured in this study do not have a logical relationship to unidirectional shifts in preferences. That does not mean learning is irrelevant, but it implies that future studies should broaden the number

Table 11 Effects of deliberation on trust, internal, and external political efficacy

	Pre-deliberation	Post-deliberation
General trust	5.0	5.14^{+}
	(1.1)	(1.1)
Internal efficacy	14.51	15.26*
	(2.9)	(3.0)
External efficacy	6.78	6.6*
	(1.9)	(1.9)

Note: Entries are scale means; standard deviations in parentheses. Minimum $N = 71$; $^{+}$ $P < 10$; * $P < .05$, paired sample, one-tailed *t*-tests

of factual questions asked and identify the kinds of knowledge that should result in opinion change in order to better demonstrate its causal effects.

Deliberation also increased two key dimensions of social capital. Afterward, panelists reported feeling more trusting of others, and they felt more capable of being able to participate in making policy. These findings are important because, in theory, they represent long-term benefits that transcend the particular event that instilled these feelings. If people come away from deliberative forums feeling empowered, they should also become more likely to try and influence the policy-making process. On the other hand, one admittedly and disconcerting outcome was finding that participants' reported external efficacy declined. Why would participants become more internally efficacious while simultaneously less likely to believe their actions will actually affect policy outcomes? This result probably stems from a significant limitation of the NCTF, and it should serve as a cautionary tale for the design of other deliberation conferences. Contrary to the Danish model, where consensus recommendations are explicitly linked to the policy-making process, the NCTF promised participants only that the organizers would disseminate their reports as widely as possible, and this situation arguably frustrated some participants.[19] Unlike the Danish tradition and political culture, there are few if any formal requests made by political bodies in the United States to conduct deliberation with the intention of acting on citizens' recommendations. Going forward, future engagement exercises should consider ways of developing concrete and meaningful policy linkages. Unless citizen engagement with science is linked to the policy process, it risks undermining the increased internal efficacy of citizens that deliberation seems to foster.

It is also important to place these findings in context. It should be obvious, for example, that the conditions facilitating deliberation in the NCTF have a questionable resemblance to the circumstances facing ordinary citizens in everyday situations. In the absence of specific support systems external to the individuals who are participating in a dialog, deliberation, properly defined, is unlikely to occur naturally. Furthermore, the topic of human enhancement was initially unfamiliar to most people who deliberated. It is possible that participants' lack of prior knowledge and strong opinions, and not the structure to these deliberations, discouraged the generation of polarization cascades in group discussions. If citizens fail to care much about a topic, many of the dynamics that result in social pressures affecting decision-making will be absent. Of course, one reason deliberation is being conducted on topics like this is because of the emphasis on upstream engagement, where informed opinions are solicited before the development trajectory is already established. Yet, if future deliberation events begin tackling more contentious policies, such as the use of stem cells, then deliberation could result in significantly different outcomes than the NCTF.

While deliberation in the NCTF seems to be primarily beneficial, it is also not clear that deliberation is necessary to arrive at these kinds of desirable outcomes. Can equally advantageous outcomes be generated by alternative and less expensive models of citizen engagement (see Powell and Colin 2009; Kleinman et al. 2009)? Lacking much empirical data, we do not have good answers. In theory, deliberation is required, but future research should empirically compare less resource intensive engagement events to those structured to promote deliberation about scientific issues.

Acknowledgments I am grateful for research assistance provided by Deena Bayoumi, feedback provided by Patrick Hamlett, NCTF collaborators at six site locations, and participants at the workshop, "Publics and Emerging Technologies: Cultures, Contexts and Challenges," Banff, Canada, October 30–31, 2009. Preparation of this article was supported by the Center for Nanotechnology in Society at Arizona State University (NSF grant # #0531194) and National Science Foundation (NSF) grant #0608791, "NIRT: Evaluating Oversight Models for Active Nanostructures and Nanosystems: Learning from Past Technologies in a Societal Context" (Principle Investigator: S.M. Wolf; Co-PIs: E. Kokkoli, J. Kuzma, J. Paradise, and G. Ramachandran). The views expressed are those of the author and do not necessarily reflect the views of NSF.

Appendix (Question wording and answer options)

Internal efficacy (all answers recorded on a 5-pt scale ranging from "strongly agree" to "strongly

[19] Several scholars involved with project gave a briefing about the citizens' reports to the U.S. Congressional Nanotechnology Caucus, Washington, D.C., March, 2009.

disagree"): "I consider myself well qualified to participate in politics"; "I feel that I have pretty good understanding of the important political issues facing our country"; "I feel that I could do as good a job in public office as most other people"; "I think that I am as well-informed about politics and government as most people"

External Efficacy (all answers recorded on a 5-pt scale ranging from "strongly agree" to "strongly disagree"): "People like me don't have any say what the government does"; "I don't think the public officials care much what people like me think"

General Trust: "Do you think most people would: (1) try to take advantage of you if they got the chance, or (2) would they try to be fair?"; "Would you say that: (1) most of the time people try to be helpful, or (2) that they are mostly just looking out for themselves?"; "Generally speaking, would you say that (1) most people can be trusted or (2) that you can't be too careful in dealing with people?"

Knowledge Questions: "Nanotechnology refers to:"; "Nanoscience is:"; "Technologies that produce significant human enhancements like making human brains able to communicate directly with computers are:"; "A 'transhumanist' is an individual who:"; "Recent developments in Nanotechnology, Biotechnology, Information Sciences, and Cognitive Sciences (NBIC) fall mostly into the area of:"; "Which of the following is expected to occur in the near future?"

Confidence: "How much confidence do you have in ["the federal government"/"Business"] protecting the public from significant risks associated with nanotechnology?" (A great deal of confidence; A fair amount of confidence; Just some confidence; Very little confidence; Not sure).

Risks Versus benefits: "What do you think about the risks and benefits of using nanotechnology for human enhancement, such as creating superior performance and longer, healthier lives?" (Risks > Benefits; Risks = Benefits; Risks < Benefits; No Opinion)

Worried: "Are you worried about nanotechnology used for human enhancement?" (Not at all worried; Yes, a little worried; Yes, very worried; No feelings)

Hopeful: "Are you hopeful about nanotechnology used for human enhancement?" (Not at all hopeful; Yes, a little hopeful; Yes, very hopeful; No feelings)

References

Ackerman B, Fishkin JS (1994) Deliberation day. Yale University Press, New Haven, CT

Barabas J (2004) How deliberation affects policy opinions. Am Political Sci Rev 98:687–701

Barber B (1984) Strong democracy. University of California Press, Berkeley, CA

Bell L (2008) Engaging the public in technology policy: a new role for science museums. Sci Commun 29:386–398

Brown MB (2006) Survey article: citizen panels and the concept of representation. J Political Philos 14:203–225

Burkhalter S, Gastil J, Kelshaw T (2002) A conceptual definition and theoretical model of public deliberation in small face-to-face groups. Commun Theory 12: 398–422

Burri RV (2009) Coping with uncertainty: assessing nanotechnologies in a citizen panel in Switzerland. Public Underst Sci 18:498–511

Cobb MD, Macoubrie J (2004) Public perceptions about nanotechnology: risks, benefits and trust. J Nanopart Res 6:395–405

Craig S, Niemi R, Silver G (1990) Political efficacy and trust: a report on the NES pilot study items. Political Behav 12:289–314

Delborne JA, Anderson AA, Kleinman DL, Colin M, Powell M (2009) Virtual deliberation?: prospects and challenges for integrating the Internet in consensus conferences. Public Underst Sci XX:1–18

Delgado A, Kjolberg KL, Wickson F (2010) Public engagement coming of age: From theory to practice in STS encounters with nanotechnology. Public Underst Sci. doi: 10.1177/0963662510363054

Delli Carpini MX, Cook FL, Jacobs L (2004) Public deliberation, discursive participation, and citizen engagement: a review of the empirical literature. Annu Rev Political Sci 7:315–344

Dryzek JS (2000) Deliberative democracy and beyond: liberals, critics, contestations. Oxford University Press, Oxford, UK

Dryzek JS, List C (2003) Social choice theory and deliberative democracy: a reconciliation. British J Political Sci 33:1–28

Einsiedel EF (2008) Public engagement and dialogue: a research review. In: Bucchi M, Smart B (eds) Handbook of public communication on science and technology. Routledge, London, UK

Einsiedel EF, Eastlick DL (2000) Consensus conferences as deliberative democracy. Sci Commun 21:323–343

Einsiedel EF, Jelsøe E, Breck T (2001) Publics at the technology table: the consensus conference in Denmark, Canada, and Australia. Public Underst Sci 10:83–98

Fischer F (2000) Citizens, Eeperts, and the environment: the politics of local knowledge. Duke University Press, Durham, NC

Fishkin J (1991) Democracy and deliberation: new directions for democratic reform. Yale University Press, New Haven, CT

Fishkin J (1997) The voice of the people: public opinion and democracy. Yale University Press, New Haven, CT

Gaskell G, Bauer MW, Durant J, Allum NC (1999) Worlds apart? The reception of genetically modified foods in Europe and the U.S. Sci 285:384–387

Gastil J, Levine P (eds) (2005) The deliberative democracy handbook: strategies for effective civic engagement in the 21st century. Jossey-Bass, San Francisco, CA

Grimes M (2006) Organizing consent: the role of procedural fairness in political trust and compliance. Eur J Political Res 45:285–315

Grundhal J (1995) The Danish consensus conference model. In: Joss S, Durant J (eds) Public participation in science: the role of consensus conferences in Europe. Science Museum, London, UK

Guston D (1999) Evaluating the first U.S. consensus conference: the impact of the citizens' panel on telecommunications and the future of democracy. Sci Technol Hum Values 24:451–482

Gutmann A, Thompson D (2004) Why deliberative democracy?. Princeton University Press, Princeton, NJ

Habermas J (1996) Between facts and norms: contributions to a discourse theory of law and democracy (W. Rehg, Trans.). MIT Press, Cambridge, MA

Hamlett P (2002) Adapting the internet to citizen deliberations: lessons learned. In: Proceedings: social implications of information and communication technology, IEEE international symposium on technology and society. Institute of Electrical and Electronics Engineers, Raleigh, NC, pp 213–218

Hamlett P, Cobb MD (2006) Potential solutions to public deliberation problems: structured deliberations and polarization cascades. Policy Stud J 34:629–648

Hamlett P, Cobb MD, Guston D (2008) National Citizen's Technology Forum: nanotechnologies and human enhancement. CNS-ASU Report # R08-0002. http://cns.asu.edu/files/report_NCTF-Summary-Report-final-format.pdf. Accessed 12 Nov 2010

Hays S (2010) A genealogical examination and grounded theory of the role of human enhancement technology in American political culture. Dissertation, Arizona State University

Hays S, Miller CA, Cobb MD (2011) Public attitudes towards nanotechnology-enabled cognitive enhancement in the United States. In: Hays S, Miller CA, Robert J, Bennett I (eds) Yearbook of nanotechnology in society: nanotechnology, the brain, and the future, vol 3. Springer, New York, NY

Hibbing J, Theiss-Morse E (2002) Stealth democracy. Cambridge University Press, New York, NY

Irwin A, Wynne B (eds) (1996) Misunderstanding science. Cambridge University Press, New York, NY

Kahan D, Braman D, Mandel GN (2008) Risk and culture: is synthetic biology different? Harvard Law School Program on Risk Regulation Research Paper No. 09-2. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1347165. Accessed 18 Nov 2010

Kleinman DL, Delborne JA, Anderson AA (2009) Engaging citizens: the high cost of citizen participation in high technology. Public Understanding Sci. doi:10.1177/0963662509347137

Kuklinski JH, Quirk PJ, Jerit J, Rich RF (2001) Political environment and citizen competence. Am J Political Sci 45:410–424

Lupia A (1994) Shortcuts versus encyclopedias. Am Political Sci Rev 88:63–76

Luskin R, Fishkin J, Jowell R (2002) Considered opinions: deliberating polling in Britain. Br J Political Sci 32: 455–487

Luskin R, Fishkin J, Hahn K (2007) Deliberation and net attitude change. Paper presented at the ECPR general conference, Pisa, Italy, September 6–8, 2007

Mackie G (2002) Does democratic deliberation change minds? Paper presented at the annual meeting of the American Political Science Association, Boston, MA

Macnaghten PM, Kearnes MB, Wynne B (2005) Nanotechnology, governance, and public deliberation: what role for the social sciences? Sci Commun 27:268–291

Mattei F, Niemi R (2005) Political efficacy. In: Bet S, Radcliffe B (eds) Polling America: an encyclopedia of public opinion. Greenwood Press, Westport, CT

Mendelberg T (2002) The deliberative citizen: theory and evidence. In: Delli Carpini MX, Huddy L, Shapiro R (eds) Research in micropolitics: political decision making deliberation and participation. JAI Press, Greenwich, CT

Morrell M (2005) Deliberation, democratic decision-making and internal political efficacy. Political Behav 27:49–69

National Science Board (2010) Science and engineering indicators 2008. National Science Foundation, Washington, DC

Nelson JW, Scammell MK, Altman RG, Webster TF, Ozonoff DM (2009) A new spin on research translation: the Boston consensus conference on human biomonitoring. Environ Health Perspect 117:495–499

Nisbet MC, Scheufele DA (2009) What's next for science communication?: promising directions and lingering distractions. Am J Bot 96:1–12

Pateman C (1970) Democracy; political participation; management; employee participation. Cambridge University Press, Cambridge, UK

Powell M, Colin M (2009) Participatory paradoxes: facilitating citizen engagement in science and technology from the top-down? Bull Sci Technol Soc 29:325–342

Powell M, Kleinman D (2008) Building citizen capacities for participation in nanotechnology decision-making: The democratic virtues of the consensus conference model. Public Underst Sci 17:329–348

Putnum R (2000) Bowling alone: the collapse and revival of American community. Simon and Schuster, New York, NY

Rawls J (1971) A theory of justice. Harvard University Press, Cambridge, MA

Roco MC, Bainbridge WS (2003) Converging technologies for improving human performance: integrating from the nanoscale. J Nanopart Res 4:281–295

Rowe G, Marsh R, Frewer LJ (2004) Evaluation of a deliberative conference. Sci Technol Hum Values 29:88–121

Ryfe D (2002) The practice of deliberative democracy: a study of sixteen organizations. Political Commun 16:359–378

Sander L (1997) Against deliberation. Political Theory 25:347–376

Savulescu J, Bostrom N (eds) (2009) Human enhancement. Oxford University Press, Oxford, UK

Scheufele DA, Lewenstein B (2005) The public and nanotechnology: how citizens make sense of emerging technologies. J Nanopart Res 7:659–667

Scheufele DA, Corley EA, Sihih TJ, Dalrymple KE, Ho SS (2009) Religious beliefs and public attitudes to nanotechnology in Europe and the United States. Nat Nanotechnol 4:91–94

Schuefele DA (2006) Messages and heuristics: how audiences form attitudes about emerging technologies. In: Turney J (ed) Engaging science: thoughts, deeds, analysis and action. Wellcome Trust, London, UK

Sclove R (1995) Democracy and technology. Guilford Press, New York, NY

Sprain L, Gastil J (2006) What does it mean to deliberate? An interpretative account of the norms and rules of deliberation expressed by jurors. Communication monograph accessed at http://depts.washington.edu/jurydem/writings.html

Stokes SC (1998) Pathologies of deliberation. In: Elster J (ed) Deliberative democracy. Cambridge University Press, Cambridge, UK

Sunstein CR (2000) Deliberative trouble?: why groups go to extremes. Yale Law J 110:71–119

Sunstein CR (2001) Designing democracy: what constitutions do. Oxford University Press, New York, NY

Sunstein CR (2003) The law of group polarization. In: Fishkin J, Laslett P (eds) Debating deliberative democracy. Blackwell Publishing, Malden, MA

Sunstein CR (2005) Laws of fear: beyond the precautionary principle. Cambridge University Press, Cambridge, UK

Wickson F, Cobb MD, Hamlett P (2011) Review of deliberative processes: National Citizens Technology Forum—USA. In: Stol E, Scholl G (eds) Democratisation of science and technology development: deliberative processes in the development of nanotechnologies. Pan Stanford Publishing, Singapore

Wilsdon J, Wynne B, Stilgoe J (2005) The public value of science. Or how to ensure that science really matters. Demos, London, UK